COMMONWEALTH OF MASSACHUSETTS

SUFFOLK, ss.

SUPERIOR COURT
CIVIL ACTION NO. 06-0790C

COMMONWEALTH OF MASSACHUSETTS,

Plaintiff,

v.

New Ventures Associates, LLC,

Defendants.

AFFIDAVIT OF MICHAEL S. HUTCHESON

I, Michael S. Hutcheson, being duly sworn, depose and say:

1. My name is Michael S. Hutcheson. I have been employed by the Massachusetts Department of Environmental Protection ("MassDEP") at 1 Winter Street, Boston, MA 02108 as the Head of the Air and Water Toxics Section in the Office of Research and Standards ("ORS") since 1988.

2. I hold a Bachelor of Arts degree in Natural Sciences from the Johns Hopkins University (1970), a Masters of Science in Biology (1972) and a PhD in Marine Sciences (1975) from the University of South Carolina, and a Masters in Public Health from the Harvard School of Public Health (1988).

3. My current job responsibilities include: (i) providing technical leadership and managing activities of toxicologists and public health professionals charged with setting air and water quality standards for chemicals used in Massachusetts; (ii) producing reviews of toxicity data; (iii) developing new human health and ecological risk assessment methodologies; and (iv) reviewing work products from staff. One component of this work involves evaluating environmental sampling data and assessing both human and ecological risks as a result of exposures to chemicals in the environment and home. I also perform statistical analyses of various types of data sets (ambient and indoor air chemical concentrations, contaminant concentrations in biological tissues), advise program staff on statistical design considerations for sampling efforts and data analysis techniques, contribute to departmental policy discussions and represent MassDEP at public, interagency and professional meetings.

4. I have been involved in the evaluation of ambient air hydrogen sulfide ("H_2S") data from around the Crow Lane Landfill since the summer of 2005. At that time, during a period of numerous odor complaints from residents around the Landfill, H_2S concentrations were above acute exposure limits and recognized odor thresholds for H_2S for 14% of the 3-day monitoring period. The measured concentrations and their durations were consistent with levels of hydrogen sulfide cited in the literature as being associated with headache, eye, throat and respiratory irritation and nausea. In November and December of 2005, air concentrations of H_2S exceeded the H_2S odor threshold for significant periods of time during which residents registered complaints of odors and adverse health-related irritation. Members of my staff and I analyzed modeling output for the landfill in 2006 and concluded that concentrations of reduced sulfur compound such as hydrogen sulfide could occur multiple times per year at levels which could be perceived as odors, could elicit irritation responses/health effects.

5. I was asked by John Carrigan, Section Chief for the Bureau of Waste Prevention's Division of Solid Waste in MassDEP's Northeast Regional Office, to comment on the significance of the hydrogen sulfide exposures in the community surrounding the Crow Lane Landfill in relation to the criteria in the Massachusetts Contingency Plan (MCP) (310 CMR 40.0000) for defining an impact to public welfare. Dr. Sandra Baird, Diane Manganaro and I presented our evaluation in the attached Memorandum (Exhibit A). Characterizing risks to public welfare includes consideration of the presence of nuisance conditions that can be represented by persistent, noxious odors in the ambient and indoor air.

6. Based upon our review of the literature, Dr. Baird, Ms. Manganaro and I concluded that:

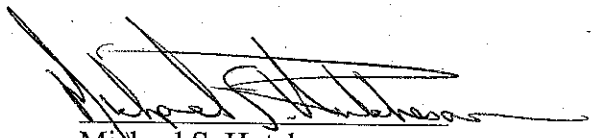
    a. Hydrogen sulfide has a pungent rotten egg odor that can be detected at very low concentrations. As concentrations increase, a spectrum of responses occurs in exposed people, starting with mild irritating responses and progressing to more severe responses. H_2S's odor is perceived immediately upon inhalation of a breath of air. Some people then experience headaches, nausea, and irritation of eyes and nose.
    b. The ability to detect the odor of hydrogen sulfide and other odorants varies among individuals, with the best estimate of the odor threshold for H_2S being in the range of 5-7 parts per billion (ppb)[1] or 7 to 10 micrograms per cubic meter (ug/m^3).
    c. Detecting an odor, pleasant or unpleasant, causes physiologic changes in discrete regions of the brain. Perceptions of an unpleasant odor can result first in the "fight or flight" response followed by effects in the nervous, respiratory and cardiovascular systems.
    d. Hydrogen sulfide can elicit both odor and irritation responses: odor being stimulated first, followed by the irritation pathway. Many individuals find H_2S odors objectionable and become annoyed.

[1] 1 ppb H_2S = 1.4 ug/m^3 H_2S

e. An individual's perception of an odor as harmful to one's health increases the symptoms (headache, nausea, eye and throat irritation)
f. Odor issues in general are of enough significance to have merited incorporation by the World Health Organization (WHO) into its criteria for development of European air quality guidelines. WHO recognizes that odor annoyance can affect the quality of life based upon its intensity, quality, acceptability and annoyance. In order to avoid substantial complaints about odor annoyance, WHO recommends H_2S concentrations not be allowed to exceed 5 ppb (7 ug/m^3) with a 30-minute averaging period.
g. There are numerous cases of people being exposed to H_2S in ambient air and in controlled laboratory situations where those exposed have reported "rotten egg" odors and ranges of health effects including increased respiratory and neurological symptoms, eye and throat irritation, headache and nausea.
h. Four states have viewed H_2S odors and the responses that they elicit to be of sufficiently significant importance to merit promulgating one-hour ambient air quality standards based upon odor recognition: California (30 ppb [42 ug/m^3]), New York, New Mexico and Kentucky all at 10 ppb (14 ug/m^3).

7. The information summarized from previous instances regarding landfill gas emissions from the Crow Lane Landfill impacting the surrounding community and the points noted above strongly support our contention that the past and continuing exposures experienced by residents in the community surrounding the Crow Lane Landfill have been persistent and noxious. Pursuant to 310 CMR 40.0994, these conditions represent a significant nuisance condition detrimentally affecting the public welfare in the community.

Signed under the pains and penalties of perjury this 26th day of July, 2007,



Michael S. Hutcheson

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY & ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

DEVAL L. PATRICK
Governor

TIMOTHY P. MURRAY
Lieutenant Governor

IAN A. BOWLES
Secretary

ARLEEN O'DONNELL
Commissioner

TO: John A. Carrigan, Chief, Solid Waste Management Section, Bureau of Waste Prevention, Northeast Regional Office

THROUGH: Carol Rowan West, Director, ORS CRW

FROM: Sandra Baird, ORS SB
Diane Manganaro, ORS DMM
Michael Hutcheson, Air and Water Toxics Group Head, ORS MH

DATE: July 26, 2007

SUBJECT: Relationship Between Odor Nuisance And Perception Of Health Effects.

1.0 INTRODUCTION

In response to your request, the Office of Research and Standards (ORS) has developed this memo clarifying the relationship between odor nuisance and perception of health effects with regard to Chapter 21E, the Massachusetts Contingency Plan (MCP) (310 CMR 40). This evaluation is being provided specifically with reference to ongoing releases of landfill gases (primarily characterized by hydrogen sulfide) from the New Ventures Crow Lane Landfill, Newburyport, MA that have been impacting the local community.

The MCP requires that the risks to public health, safety, public welfare and the environment be characterized (310 CMR 40.0094) at locations falling within the scope of the 21E program. Both quantitative and qualitative evaluations of risk to public welfare and the environment are employed to determine the need for a remedial action or to demonstrate that a condition of No Significant Risk exists or has been achieved (310 CMR40.0992 (3)).

The MCP notes that the consideration of the public's welfare includes the existence of nuisance conditions (310 CMR 40.0994 (2)). From language in the regulation employed to describe how nuisance conditions need to be characterized, nuisance conditions represent, in part, the presence of **persistent, noxious odors in ambient and indoor air** (CMR 40.0994 (4)(a) 1). Therefore

situations where there are persistent and noxious odors represent nuisance conditions which are an impact on public welfare under the terms of Chapter 21E.

2.0 BACKGROUND

In a series of evaluations of field and model-generated data associated with the Crow Lane Landfill, we have described conditions that represent nuisance conditions in our professional opinions.

In August 2005 we evaluated monitoring data from a 3-day period that month (Hutcheson 2005). "Ambient air hydrogen sulfide concentrations measured at a fixed point continuously .... during a period of major odor complaints from residents around the Crow Lane Landfill were above the acute exposure standard of 30 ppb (42 ug/m^3) from California and were above recognized odor thresholds for H_2S for 14% of the monitoring period. The measured concentrations and their durations were consistent with levels of hydrogen sulfide cited in the literature as being associated with headache, eye, throat and respiratory irritation and nausea".

We also evaluated data from an approximately 2 month period later that same year taken during a period of frequent and vocal residents complaints about noxious odors from the landfill (Hutcheson, not dated). Our conclusions were "that H_2S ambient air concentrations at the fixed monitor located near the landfill boundary often exceeded the H_2S odor threshold for significant periods of time (hours) during November through December 2005. There were repeated instances of events when H_2S concentrations were above the odor threshold (222 discrete events lasting from >10 minutes to almost 18 hours). Local citizens registered complaints, noting both odor and adverse health-related irritation at times that corresponded to the detection of H_2S concentrations above the odor threshold. This analysis clearly documented the existence of unpleasant, irritating and often noxious air quality conditions in the vicinity of the New Ventures Associates LLC Crow Lane Landfill in Newburyport, MA most likely due to H_2S from the landfill.

In August 2006, we reviewed the results of an ambient air computer dispersion modeling study of chemicals projected to be released from the landfill open flare at the Crow Lane Landfill (Manganaro et al. 2006). Simulations were run for different operating conditions at the landfill. Exceedances of health-based acute exposure limits for reduced sulfur chemicals such as H_2S were predicted to occur multiple times per year under different sets of operating conditions. Health effects including headache, nausea and throat irritation are the typical short-term effects associated with acute exposure to these chemicals. In addition, people with asthma or individuals who may already be compromised with sensitive respiratory systems or cardiovascular systems could experience more serious effects from such exposures. In the same way, an exceedance of the SO_2 national ambient air quality standard (NAAQS) (USEPA 1996) could be of particular concern to those with asthma or breathing difficulties. The results of that evaluation were consistent with the many complaints received from residents living near this landfill. The standard used to evaluate H_2S represents a level at which both health effects and odors have been documented in studies conducted with people.

Just recently, complaints from neighbors around the landfill have started again. While the new air monitoring data have not been thoroughly analyzed for this latest situation, an initial look at the results, reviewed together with the complaints, the nature of the complaints, the presence of an obvious source of chemical(s) which could elicit these types of complaints and the well-documented previous responses and effects strongly suggest that residents continue to be impacted by landfill gas emissions. The technical information supporting the link between exposures and effects follows.

3.0 HYDROGEN SULFIDE, ODOR AND HEALTH EFFECTS

Hydrogen sulfide has a pungent rotten egg odor that can be detected at very low concentrations (ATSDR 2006). As concentrations increase, a spectrum of responses occurs in exposed people starting with more mild irritant responses progressing to more severe responses. The transitions between these types of endpoints are not clear and vary between individuals. In addition, the distinction between what constitutes "adverse health effects" and irritant effects is not clear. Our position is that the irritant responses associated with low level acute exposures represent adverse health effects. H_2S's odor is perceived immediately upon inhalation of a breath of air. After detecting the odor of H_2S, some people experience headaches, nausea, and irritation of eyes and nose (ATSDR 2006; USEPA 2003). Olfactory fatigue resulting in inability to detect the odor may occur beginning at concentrations of 100 ppm (140 mg/m^3)[1] (USEPA 2003). Paralysis of the olfactory nerve has been reported at 150 ppm (210 mg/m^3) (Beauchamp et al. 1984). Decreased olfactory function and neurobehavioral effects have been reported following long-term continuous exposure of workers to occupational levels of hydrogen sulfide (USEPA 2003).

3.1 Odor Detection Thresholds

The ability to detect the odor of hydrogen sulfide and other odorants varies among people. An odor detection threshold is defined as the concentration of the substance where half (50%) of the people in a test group can detect the presence of an odor. A limitation of this operationally-defined limit is that theoretically nearly half of the population can detect odors below the "threshold." The best estimate of the odor threshold for H_2S is in the range of 5-7 ppb (7 to 10 ug/m^3) (Amoore 1985; WHO 2000). However, the odor detection threshold for H_2S varies by more than 2 orders of magnitude among individuals, with the level of detection ranging from 0.5 to 300 ppb (0.7 to 420 ug/m^3) reported by ATSDR (2006). A wider range of odor thresholds, 0.072 – 1400 ppb (0.1 ug/m^3 to 1960 ug/m^3), was reported by Amoore (1985) based on 26 studies in the primary peer reviewed literature from 1848 through 1979.

[1] 1 ppm H_2S = 1.4 mg/m^3 H_2S, 1 ppm = 1000 ppb; 1 ug/m^3 = 1000mg/m^3

3.2 Odor Physiology

Odor is perceived immediately upon inhalation of a breath of air. Detecting an odor, pleasant or unpleasant, causes physiologic changes in discrete regions of the brain (Zald and Parto, 1997).

Detecting an *unpleasant* odor induces physiologic changes associated with the stress response, initially causing the "fight or flight" response and the release of epinephrine and cortisol. The endogenous chemicals released during the stress response can have direct effects on the nervous, respiratory and cardiovascular systems (Zald and Parto 1997; Smith 1999; Roth and Goodwin 2003).

Volatile chemicals, such as hydrogen sulfide, can elicit both odor and irritation responses. The odor and irritation responses arise through separate neurological pathways. For a chemical with both odor and irritant properties, such as hydrogen sulfide, the odor pathway is generally stimulated first, followed by the irritation pathway as the chemical concentration in air increases (Shusterman 2001).

3.3 Odor Annoyance and Health Effects

Individuals that detect the odor of H_2S may feel annoyed[2] and find it objectionable[3]. Individuals inherently perceive different levels of annoyance from exposure to environmental stressors mediated by sensation, including stressors such as odor, noise, and irritation; those more annoyed by one stressor are also more annoyed by others (Winneke 1992). Perceived poorer health status and younger age were found to be predictors of increased odor annoyance, while anxiety, emotional lability or extroversion/introversion were not (Winneke 1992). However, ***frequency of odor events per year*** was found to be the most important single factor modulating odor annoyance (Winneke 1992).

An individual's perception of an odor as harmful to one's health increases the symptoms (headache, nausea, eye and throat irritation) (Shusterman et al. 1991; Shusterman 2001; Dalton et al. 1997; Dalton 2002).

4.0 CRITERIA FOR CONSIDERING SENSORY EFFECTS

The World Health Organization (WHO) developed criteria for considering sensory effects, such as odor, during the development of *Air Quality Guidelines for Europe*, WHO (2000). As a result of that effort, they conclude that "although odor annoyance cannot be regarded as an adverse

---

[2] Defined by *The American Heritage Dictionary* (2000) as, 1) to cause slight irritation to (another) by troublesome, often repeated acts, 2) to harass or disturb by repeated attacks.

[3] Defined by *Dictionary.com Unabridged (v 1.1)*(based on the *Random House Unabridged Dictionary*, Random House, Inc. 2006) as, 1) causing or tending to cause an objection, disapproval, or protest; 2) offending good taste, manners, etiquette, propriety, etc.; offensive. *Synonyms:* unacceptable, offensive, vile, odious.

effect in a strict sense, it does affect quality of life. " They consider three characteristics when evaluating odor: intensity; quality; and acceptability and annoyance. Where,

- Intensity is described by the detection threshold level;
- Quality is described by the recognition threshold, i.e., "the lowest concentration at which the sensory effect, such as odor, can be recognized correctly in 50% of the cases; and
- Acceptability and annoyance is described by the nuisance threshold level, i.e., the concentration at which not more than a small proportion of the population (less than 5%) experiences annoyance for a small part of the time (less than 2%); since annoyance will be influenced by a number of psychological and socioeconomic factors, a nuisance threshold level cannot be defined on the basis of concentration alone."

WHO also considered whether the effects of irritation and headache should fall into the category of annoyance or health endpoint, concluding that headache is a health endpoint (WHO 2000).

WHO (2000) concluded that "in order to avoid substantial complaints about odor annoyance among the exposed population, H_2S concentrations should not be allowed to exceed 5 ppb (7 ug/m^3), with a 30-minute averaging period." They also recommended a more classical health-based exposure guideline value of 107 ppb (150 ug/m^3) for H_2S with an averaging time of 24 hours to prevent eye irritation and changes in heme synthesis.

4.1 Population Health Effects Following Acute H_2S As Part Of The Ambient Air Exposure Mixture

Residents living near meat packing plants and tanneries releasing hydrogen sulfide and other sulfur containing chemicals, measured as total reduced sulfur (TRS), into ambient air complained of a "rotten egg" odor and reported a range of health effects that included increased respiratory and neurological symptoms (Campagna et al. 2004). An ambient air concentration of H_2S or TRS greater than 30 ppb (42 ug/m^3) (30 minute rolling average) the previous day was associated with a 25% increase in the number of unscheduled emergency room or outpatient visits from children and adults for treatment of respiratory diseases including asthma (Campagna et al. 2004).

Objectionable odor, eye and throat irritation, and headache and nausea were reported by six workers exposed to 90 ppb (126 ug/m^3) (30 minute down-wind average) H_2S downwind from an oil refinery. The exposure lasted for 5 hours; most symptoms went away within a few hours after exposure ended. However, some staff reported throat irritation throughout the following day (TNRCC 1998).

Increased eye, nasal, and throat symptoms, along with breathlessness and headache were reported in a concentration dependent manner by adult residents exposed to H_2S from pulp mills at levels greater than local background concentrations, i.e., >10 ug/m^3 TRS (~5 ppb [7 ug/m^3] H_2S, assuming H_2S is 2/3 of TRS). Reporting of nausea was significantly increased by residents when exposures were >30 ug/m^3 TRS (~20 ug/m^3 [14 ppb] H_2S) (Marttila et al., 1995). Components of the local ambient air mixture included H_2S, methyl mercaptan, and methyl sulfides; all have strong odors detectable at low concentrations. SO_2 was also present in the

ambient air at concentrations ranging from 4-16 ug/m^3 during medium exposure periods and 20-50 ug/m^3 during the high exposure periods (Marttila et al. 1995); all SO_2 concentrations were below the SO_2 National Ambient Air Quality Standard for continuous exposure of 80 ug/m^3 (USEPA 1996). Chemicals in addition to hydrogen sulfide can play a role in the perception of odor since some (e.g., mercaptans) have odor detection/recognition thresholds orders of magnitude lower than hydrogen sulfide.

4.2 Health Effects Following Acute H_2S Exposure In Controlled Experimental Studies

Better documentation between exposure levels of H_2S and reported adverse health effects can come from controlled human exposure studies than from field observations. However the limitation with experimental studies employing volunteers is that the volunteers are often self-selected, healthy, and the exposure is anticipated. Their responses may not fully represent those of all segments of the population. These controlled exposure studies are also typically carried out at higher concentrations than measured around landfills and responses of study subjects may be more intense and represent more severe effects.

Ten volunteers, 3 males and 7 females, with medically controlled bronchial asthma were exposed to 2 ppm (2.8 mg/m^3) H_2S for 30 minutes in a sealed chamber (Jappinen et al. 1990). Volunteers had been off their asthma medication for 2 days prior to exposure. Their respiratory function was assessed before and immediately after exposure. No statistical changes in respiratory function were observed when the individuals were evaluated as a group. However, two of the ten volunteers had changes that were greater than 30%, in two functional parameters associated with bronchial obstruction. The changes in airway resistance were not reflected in the volunteer's clinical condition (Jappinen et al. 1990). Three of the ten volunteers reported headache following exposure. The authors report that the volunteers found the odor very unpleasant initially, but rapidly became accustomed to it. Volunteers also reported dryness of nose and throat during the exposure period (Jappinen et al. 1990).

A series of studies in healthy male and female volunteers were conducted evaluating physiologic responses of the respiratory and cardiovascular systems and skeletal muscle following exposure to H_2S while breathing through their mouths only[4]. Forty-two volunteers exposed to 2.5 to 5 ppm (3.5 to 7 mg/m^3) H_2S for 15 minutes experienced coughing and throat irritation (Bhambhani and Singh, 1985). Significant changes in muscle aerobic metabolism, but no significant respiratory or cardiovascular effects were found in two separate studies, one of males exposed to 5 ppm (7 mg/m^3) H_2S (Bhambhani et al. 1996) and the second of males and females exposed to 10 ppm (14 mg/m^3) H_2S (Bhambhani et al. 1997), both groups were exposed for two 30-minute sessions while exercising. These results suggest an inhibition of aerobic capacity of the exercising muscle with a switch to anaerobic metabolism (Roth and Goodwin 2003; ATSDR 2006; Bhambhani and Singh 1997). Exposure by oral inhalation prevents the volunteer from smelling the odor of H_2S by preventing exposure of the nasal passages, and may prevent systemic effects that are mediated through the nasal pathway.

[4] Volunteers breathed only through their mouths, thus did not have exposure to their noses or eyes.

5.0 STANDARDS FOR HYDROGEN SULFIDE IN AMBIENT AIR

Four states have promulgated 1-hour ambient air quality standards for H_2S based on perception of odor.

California derived an ambient air quality standard (CA AAQS) for a one-hour exposure to H_2S of 30 ppb (42 ug/m^3). The CA AAQS for H_2S is not to be equaled or exceeded. It was derived to be protective of adverse effects in a human population, including sensitive subgroups (CA EPA, 2006). It represents the mean of the odor threshold reported by 16 individuals and is therefore based on health effects associated with perception of odor. However, California acknowledged that their standard might need to be reexamined in light of other information, including one study (commissioned by CA EPA) that concluded that 83% of the population would be able to detect the odor of H_2S at 30 ppb (42 ug/m^3) and 40% would find this level to be an objectionable concentration (Amoore 1985). The California Air Resources Board, in public testimony, noted that some people reported headaches and other symptoms at concentrations less than 30 ppb (42 ug/m^3) (CA EPA, 1999).

Three states, New Mexico, New York and Kentucky, have a one-hour ambient air standard for H_2S of 10 ppb (14 ug/m^3). The New York 1-hour AAQS is intended to "prevent disagreeable odors" and is not to be exceeded more that once per year (NYS DEC Rules and Regulations, Subpart 257-10). The New Mexico 1-hour AAQS is a one-hour average that is not to be exceeded more than once per year (20.2.3.110 NMAC). The Kentucky 1-hour average AAQS is a secondary standard that is not to be exceeded more than once per year (401 KAR 53:010). At an ambient air concentration of 10 ppb (14 ug/m^3), it has been estimated that 56% of people will detect H_2S and 17% will find it annoying (Amoore, 1985).

6.0 CONCLUSIONS

The information summarized from previous occasions with landfill gas emissions from the Crow Lane Landfill impacting the surrounding community and the literature noted in document strongly support our contention that the past and continuing exposures experienced by residents in the surrounding community have been persistent and noxious. Pursuant to 310 CMR 40.0994, this situation in our opinion represents, at a minimum, a significant nuisance condition detrimentally affecting the public welfare in the community.

7.0 REFERENCES

The American Heritage Dictionary of the English Language. 2000. Fourth Edition, by Houghton Mifflin Company.

Agency for Toxic Substances and Disease Registry (ATSDR). 2006. Toxicological profile for Hydrogen Sulfide. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. http://www.atsdr.cdc.gov/toxprofiles/tp114.html

Amoore, J.E. 1985. The perception of hydrogen sulfide odor in relation to setting an ambient standard. Prepared for California Air Resources Board, ARB Contract A-4-046-33.

Beauchamp, R.O., Jr., Buss, J.S., Popp, J.A., Boreiko, C.J., Andjelkovich, D.A., Leber, P. 1984. A critical review of the literature on hydrogen sulfide toxicity. Crit. Rev. Toxicol. 13:25-97. [As cited by USEPA, 2003.]

Bhambhani, Y and Singh, M. 1985. Effects of hydrogen sulfide on selected metabolic and cardiovascular variables during rest and exercise. Report submitted to Alberta's Health and Safety and Compensation. June, 1985. [As cited by CalEPA, 1999.]

Bhambhani, Y, Burnham, R., Snydmiller, G., et al. 1996. Effects of 5-ppm hydrogen sulfide inhalation on biochemical properties of skeletal muscle in exercising men and women. Am. Ind. Hyg. Assoc. J. 57:464-468. [As cited by ATSDR, 2006.]

Bhambhani, Y, Burnham, R., Snydmiller, G., et al. 1997. Effects of 10-ppm hydrogen sulfide inhalation in exercising men and women. J. Occup. Environ. Med. 9:122-129. [As cited by ATSDR, 2006.]

California Environmental Protection Agency (CA EPA). 1999. Acute toxicity summary hydrogen sulfide. http://www.oehha.ca.gov/air/acute_rels/pdf/7783064A.pdf

California Environmental Protection Agency (CA EPA). 2006. Ambient Air Quality Standards, California Air Resources Board (5/17/2006). http://www.arb.ca.gov/aqs/aaqs2.pdf

Campagna, D.C., Kathman, S.J., Pierson, R., Inserra, S.G., Phifer, B.L., Middleton, D.C., Zarus, G.M., and M.C. White. 2004. Ambient hydrogen sulfide, total reduced sulfer, and hospital visits for respiratory diseases in northeast Nebraska, 1998-2000. J. Exp. Environ. Epi. 14:180.

Dalton, P. 2002. Odor, irritation and the perception of health risk. Int. Arch. Occup. Health 75:283-290.

Dalton, P., Wysocki, C.J., Brody, M.J. and Lawley, H.J. 1997. The influence of cognitive bias on the perceived odor, irritation and health symptoms from chemical exposure. Int. Arch. Occup. Health 69:407-417.

Hutcheson, M. 2005. Evaluation of Hydrogen Sulfide Continuous Monitoring Data from August 5-8, 2005 from Wildwood Dr., Newburyport, MA. Memorandum dated August 24, 2005 to John Carrigan, MassDEP, Bureau of Waste Prevention. Office of Research and Standards, Massachusetts Department of Environmental Protection. Boston, MA.

Hutcheson, M. not dated. Review of November – December, 2005 Air Monitoring Data (Hydrogen Sulfide) from Charmanski Drive, Newburyport, MA. New Ventures Crow Lane Landfill. Internal unpublished memorandum. Office of Research and Standards, Massachusetts Department of Environmental Protection. Boston, MA

Jappinen, P., Vikka, V., Marttila, O., and T. Haahtela. 1990. Exposure to hydrogen sulphide and respiratory function. British J. Industrial Medicine 47(12):824-8.

Kentucky Regulations 401 KAR 53:010

Manganaro, D., Baird, S., and M. Hutcheson. 2006. Evaluation of Ambient Air Modeling Results for the Crow Lane Landfill, Newburyport, Massachusetts. Memorandum dated August 24, 2007 to John Carrigan, MassDEP, Bureau of Waste Prevention. Office of Research and Standards, Massachusetts Department of Environmental Protection. Boston, MA.

Marttila, O., Jaakkola, J.J.K., Partti-Pellinen, K., Volkka, V., Haahtela, T. 1995. South Karelia air pollution study: daily symptom intensity in relation to exposure levels of malodorous sulfur compounds from pulp mills. Environ. Res. 71:122-127.

New Mexico Regulations 20.2.3.110 NMAC

NYS DEC Rules and Regulations, Subpart 257-10. Last revision of the rule 8/9/1977.

Roth, S. and Goodwin, V. 2003. Health effects of hydrogen sulfide: knowledge gaps. Alberta Council for Research for Air and Health. http://environment.gov.ab.ca/info/library/6708.pdf

Shusterman, D. 2001. Odor-associated health complaints: competing explanatory models. Chem. Senses 26:339-343.

Shusterman, D., Lipscomb, J., Neutra, R. and Satin, K. 1991. Symptom prevalence and odor-worry interaction near hazardous waste sites. Environ. Health Persp. 94:25-30.

Smith, C.J., Scot, S.M. and Ryan, B.S. 1999. Cardiovascular effects of odors. Toxicol. Ind. Health 15:595-601.

TNRCC (Texas Natural Resources Conservation Commission) 1998. Memo from Tim Doty to JoAnn Wiersma. Corpus Christi Mobile Laboratory Trip, January 31- February 6, 1998; Real-Time Gas Chromatography and Composite Sampling, Sulfur Dioxide, Hydrogen Sulfide, and Impinger Sampling. April 20, 1998. [as cited by USEPA 2002.]

U.S. Environmental Protection Agency (USEPA). 1996. National Ambient Air Quality Standards for Sulfur Oxides (Sulfur Dioxide) – Final Decision. Federal Register 61(100):2556-25580.

U.S. Environmental Protection Agency (USEPA). 2002. Hydrogen sulfide, interim acute exposure guideline levels (AEGLS) draft for NAS/COT subcommittee for AEGLs. November 2002.

U.S. Environmental Protection Agency (USEPA). 2003. Integrated Risk Information System (IRIS) for hydrogen sulfide (H_2S). Last checked 7/25/2007. http://www.epa.gov/iris/subst/0061.htm

Winneke, G. 1992. Structure and determinants of psychophysiological response to odorant/irritant air pollution. Ann. NY Acad. Sci. 641: 261-276.

WHO (World Health Organization). 2000. Air quality guidelines for Europe. 2cd edition. WHO Regional Publications, European Series, No. 91.

Zald, D.H. and Parto, J.V. 1997. Emotion, olfaction, and the human amygdala: amygdala activation during aversive olfactory stimulation. Proc. Natl. Acad. Sci. USA 94:4119-4124.